Following is a report on my findings on the thermal treatment of flints by the Stoneage People in making artifacts, not to include obsidian, ignumbrites or opalites, some flints and jaspers.

There must be a basis for all that has been written about the heating of stones by the Primitives in making artifacts by fracture, breaking and cleaving, but nothing has been recorded, to my knowledge, of tempering. We find, even in the Boy Scout manual, the statement that water dropped on heated stones would produce an arrowpoint. There are many different explanations and methods published by persons on this subject regarding various thermal methods used and, in fact, some of these writers have vouched that they have seen the Indians use this method. Some have stated that the Indian rubbed a bow string up and down against the piece of flint to create frictional heat, dipping it in water during this process, and thereby causing a piece of flint to pop off the edge of the working stone. They claim that by repeating this process, that primitive man would eventually flake and shape a point. Others claim that he used a piece of wet buckskin or pine needles against the hot stone in order to make an artifact. Yet, I doubt very much if any point was ever made by using these methods. A close study of the surface of any artifact will quickly reveal that pressure or percussion - and not a thermal fracture - was used to remove the flakes and shape a point.

It is possible that early man used the principle of the sand bath by placing his rough chips in the household fire and leaving them there for several days in order to get the proper texture for making his point by pressure and percussion. By leaving his rough material in the hot sand for several days, the stone would lose the water of crystallization, thereby changing the refractive index of the stone and resulting in a much more glassy piece of workable material. This heating was necessary because in an unheated piece of stone one still has the problem of the natural intertwining crystals of the coarse, tough material. Unheated material could only produce rough tools, for it would not result in a sharp cutting edge. After the material is heated and worked, it will produce a tool edge similiar to obsidian. When Ancient Man wanted a tool with a good, sharp cutting edge, he heated the stone before making the point, but for drills, agricultural tools, axes etc., for which he required no razor cutting edge, but just stone strength and toughness, he left the material in its natural form for making his implements.

While hunting in the deserts and mountains for gem stones, I have found numerous quarry sites of the Indian and these sites very often were of flint, agate and the quartz family minerals. Both at the stone quarry sites and also in the campgrounds, I have found strong evidence of the heat treatment of stone before working the tool. At both the camp and quarry sites, I have collected both heated and unheated chips, chunks of material, and tools; and have been experiments with this material for a good many years. The results of my experiments have proven to me that to make an arrowpoint, particularly with pressure flaking and hand retouching, the stone must first be heat-treated before any satisfactory work can be done. I have used the same material, both heated and untreated, in making artifacts. In its natural state, I find that stone of a granular texture will not stand the necessary pressure - nor does it have flexibility enough to produce a sharp-edged tool. However, after I have properly heated this same material, I find that it will produce a fine, properly flaked, sharp-edged tool similar to Indian points I had found at the nearby campsite.

I have studied both the points from the Lindenmeyer sites and the collection of Dr. Roberts from Colorado and they all show very definitely the example of heat treatment of the stone before the tool was fabricated. They all have a definite shiny appearance, which is a direct result of the heating of the stone, for one knows that these materials do not have this lustre in their natural state.

Upon careful examination and close study of a pressure worked point of agate, jasper or flint, one will find that they ~~all~~ have a lustrous, shiny texture and that they have a marked degree of sharpness on the blade's edge. It would be impossible to obtain this sharp edge by working the material in its natural state because of the natural granular texture of ~~the~~ native stones. In the quarry sites, where the Indian roughed out his material and took spalls, one will note that the stone is sugary in texture and is extremely tough in its untreated state and that the same material chips - after heat treatment - do no resemble, in any way, the original stone. Another way to identify heat-treated stone chips and spalls is to note that some of the minerals that are in combinations with the silicas have been definitely altered by the heat. Yellow liminites change to hemitites and the color becomes a more brilliant red and, usually, the changed stone does not appear to be native to the surrounding materials in situ.

Not all stone were heat treated by primitive man. Obsidians, opalites, ignumbrites and some jaspers and agate, which are on a border-line of agate and opal, were easily worked and the early man found it unnecessary to heat these varieties before making his tools. But most agate, jaspers, and flint materials, particularly where one find salicified clay and kidney-like nodules and concretionary stones, have been changed by the heat method - for these stones are very granular in texture and it is next to impossible to work a finely-chipped artifact. The Hopewellian people in central Ohio, from Flintridge, Ohio quarry site, used this heat treatment in making their knives and points. In studying the points found there, one will notice that they are much more lustrous than the natural stone found in this area, particularly Flintridge, Ohio flint.

In our local Idaho campsites, we find many pieces and chips that indicate that the natural stone was overheated. As indicated before, the Indian left the rough stone in the sand under the campfire, but, since he had no way of determining the degree of heat of the fire, and, also, since all stone do not require the same degree of heat for treatment, one will very often find a discarded, over-heated, piece of stone in the campsite. Heating the stone will reduce the crystallization in size, making the material almost opal in texture and it will almost resemble obsidian in texture. However, heating the material makes the stone even better and more workable than obsidian. ONE CAN BEND THE FLAKE PAST THE CENTER OF THE ARTIFACT TO PRODUCE THE FINE RIPPLE FLAKING

Heating does not make the material harder, but yet it is more flexible and longer and narrower flakes can be removed with a well-treated piece of agate, jasper or flint. However, if the stone has been overheated, it will produce a granular or crazing effect. Indication of over-heating are checks in the material - or, it might change to crystobolite or tridimite, depending on the degree of heat it was subjected to. I believe some of the quartz family minerals are called the geological pyromoters and that they will even indicate the maximum heat degree of various places or depths of the earth. One can often find surface stones in a wooded area that has been fired and these stones will show a definite heat change, such as color, crazing, and one will even find some stones that have not been overheated which will show the glassy opal-like change. Not all heat-treated stones used by the Indians were altered by their effort. They, too, found stones which had been in a forrest or brush fire and they were quick to use these for making their points. Yellow agate, when heated will change to a carnelian agate. And we know, from Germany, that by soaking certain agates in an iron solution, one can produce carnelian agate

artificially. For this, the Germans usually used Brazillian agate, which they would soak in a solution of iron nitrate. They would then heat the stone in a castiron flask until the flask glowed a dull red and, thereby, the iron nitrate, which had penetrated the agate, would change to an iron hemitite, which would produce their artificial Carnelian agate.

At the present time I am using a ceramic oven to test the heating of stones for making points. However, before I started using this kiln, I used a pan of sand and the kitchen range oven and found that by leaving the stone in the oven for a period of weeks at about 400 degrees was just about right. When I used this method, I was experimenting with an old Majestic coal range and, therefore, can not accurately determine the oven degrees, but I assume it to be about 400. Because of this uncontrolled heat, I received both good and bad results. However, I find now that by using a controlled oven and experimenting with different types of agates and flints, that I can determine the degree of heat needed for each type of stone and, thereby, get just about the results needed to change the stone to good working material.

The material I have been working with recently is from an Indian quarry site on Antelope Creek, for there I find material in great quantity and variety. Primarily, it is a jasper-agate type of material, but one also finds tube agate in the same quarry. At this site, one can easily see the evidence of rejects by Ancient Man when the material contained vugs, pits, or crystal pockets. At this quarry, I find stone only in its original state, but about three miles from the quarry, in what appears to have been their home camp, one finds the same material which has been heat-treated and fabricated into knives, blades, etc. A lot of skill is required to properly heat-treat stone in preparation for working, and this is a very important part of flint knapping that has been overlooked in the study of the art of making artifacts. To date, I have found nothing written on this subject, yet I feel it was contemporary with the lithic industries of the Stone Age Man.

When using the temperature regulated kiln for treating stones, I use a pan filled with blow sand from the desert near Twin Falls. The stone is buried in this sand and must be heated very slowly and cooled very slowly and, in fact, it should be allowed to cool about 24 hours before it is removed from the oven. Any quick change in temperature, such as even opening the oven door, will result in checking and crazing the material.

From the rough stone, I suppose the Indian would remove spalls, worked very thin and just about the size of the finished ~~blade~~ artifact, to place in the sand beneath the campfire for heat-treating. If the stone was left in nodule form or in a massive piece, the perimeter, or outside of the stone would be hotter than the center and also the outside would cool more rapidly and, thereby, cause the stone to check or fracture which would result in worthless material that the worker would discard because it would not be of workable quality. However, if the stone was split first and made thin, then the heat would be more uniform and checking and cracking would be avoided. The oven which I use for my experiments does not have a pyrometer, but I have found that by putting an iron bolt on top of the sand of the buried stones that I can just about tell when the oven has reached the desired heat. When this bolt has turned the faintest cherry tinge of red, it has reached the desired heat and I find when a variety of material is heated at the same time that certain stones will be overheated and worthless while others will be in a perfect working condition. How to give a fool-proof formula for heating stones seems to be an impossible thing to do for each type of material requires different timing and different heat degrees, and, to date, I have had to be guided by guess work or the trial and error method. I have observed, however, that the agate that checked and became worthless seemed to be of the variety which was already of a glassy texture before it was placed in the kiln. Agates of a more crystalline substance will generally stand a greater degree of heat and I presume this is because of the higher degree of porosity. Agates that are more of the common opal texture will even stand less heat.

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While working at the Ohio State Museum lithic laboratories, I tested several pieces of stone and conducted several experiments on this subject, nothing to any great degree of intensity, but I did take some pieces to the Battell Institute and they used an electronic microscope and found that the crystalline structure of the materials had been altered considerably and that they might even be used as measurements of the crystal structure after they were treated.

In one of my tests, I used a piece of flint from France. From this material I knocked a spall from one side of the original big flat chip and made an arrowpoint. However, I left a hinge fracture at the basal portion of the arrowhead so I could fasten it back to the original stone. The result is the appearance of an arrowhead shot into a block of stone. The portion of this flint made into an arrowpoint had been heat-treated before I made the point and one can readily see the remarkable change that took place as a result of the heating. The color of the stone has changed and it is much more lustrous and glasslike. Had I used the flint chip without heatint, I could not have produced the fine flaking or sharp edge that shows on the point.

Sometimes one will find in very old artifacts that, after the stone has been treated and the crystal reduced in size, the material is not at a normal state so it has a tendancy to go back to its original state or to return to the original length of crystal. One might compare it to glass being melted which wants to go back to the original form so it is under a stress and strain and eventually resumes its original granular texture as is shown by a fresh flake removed from an old heated artifact.

One does need a pyrometer and a temperature control unit in order to get the exact temperature needed to treat stones. One should have a block of natural flint from the quarry site and it should be diamond sawed in probably one inch squares. Then one should start a series of tests of this material, using different degrees of heat on each piece of stone, and keep notes on the amount of change that takes place under different degrees of heat in order to ultimately arrive at the correct amount of heat needed to produce a working piece of material. Different material should be experimented with from various quarry sites to determine structure changes and to determine ages. It is my belief that ancient man has been using the heat treatment for the past 10,000 years, at least as old as Folsom man. It is also my belief that this heat treating was contemporaneous with the flintworking industries.

Ancient man may have used this method sometimes in quarrying stones by maybe chilling some it in order to get some crevice opened up or to provide a fulcrum but the material that they could recover would chill and break. The stone would be checked and it would be worthless for artifacts. If a piece of stone is chilled and cracked, it has a tendancy to crack in a cubical form. There is no doubt that ancient man used the heat treatment, not only in treating the stone prior to flaking, but also in quarrying. I have seen signs where the outside of a large mortor was heated to remove a portion of the rock and make the mortor more spherical. The mortor showed evidence on the outer edge of being heated and then chilled.

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Further experiments of thermal treatment of Silicious Materials and results:

I have now treated various types of stone and have heated them to varying degrees. For one experiment I used an Indian core found at the quarry site on Antelope Creek. This is an unheated core discarded at the site, due to the Indian's habit of using a core to spall off pieces in preparation for making points. It is of a non-translucent chirty material, rather like a white jasper with yellow flecks and yellow banding. I removed a spall from this unheated piece and treated it at about 1100 degrees and it altered the yellow or amber color to a red. The white remained the same. Yet the material became considerably more glassy and less granular. I have made a point from this heat-treated piece of material and attached it to the original untreated core to show what a difference the thermal treatment makes. This point can be removed from the original core for close inspection, for it is only attached with modeling clay. This will clearly point out the change that takes place as a result of the thermal treatment.

I also experimented with a piece of material from France, where many of the fine artifacts were produced. It is a yellowish or amber-colored material, semi-translucent, but is made up of many intertwining crystals which give it a sugary texture, and extreme toughness. Untreated, the stone is extremely tough and almost impossible to work by pressure. By percussion it is possible to spall it off and make rough tools, but in its natural state it is not good for working fine points. With heat, the stone changed to a reddish color, became much more flexible and had the same glassy texture of most heated stones. After heating this stone, I was able, by pressure, to remove a flake an inch and a half long and found that it worked very much like obsidian. In fact, it seems to have even a little more flexibility than obsidian, for I found that in detaching a flake, after treatment, one has to be careful to regulate more carefully the pressure on this stone for the flakes would curve more easily and would even remove the opposite edge of the stone and this was impossible to do with this stone in its normal or untreated state. In its natural state, the stone was coarse and had no flexibility or sharpness. After making a point from this heat-treated piece, I attached it to the original natural core to demonstrate the difference after heat treating.

Another example of material used was from the Quarry site on Antelope Creek. This was a white material with yellow colorings throughout. I used the entire core for heat treating and then, after the treatment, I removed a spall to use in making my point. I have also attached this back to the original spall. One will note that the yellow changed to a dark red and the white remained white. This will demonstrate just how heating will improve the quality of the stone so that longer flakes can be taken. In working this point I broke the piece, for I exerted more pressure than a heated piece requires. However, I attached the broken pieces together for purposes of examination and study.

From a campsite on Antelope creek I collected some flakes, which all show evidence of heat treatment. In the campsite I found the original spall from the quarry and the flakes that had been removed from this spall and they were heat-treated and then chipped. The flakes that were removed from the heat-treated piece of stone, while making a point, still showed the original granular surface while the artifact itself had the glassy and lustrous character achieved by heat-treatment. These flakes show the original spall as it was taken off then it was heat-treated - then worked again and the second time when it was worked there is still some facet or part of the original material or original surface from the quarry work left on the outside. I found numerous pieces showing evidence of this work. Then in other campsites I have found

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many fragments and pieces that have been heat-treated that still show some of the original outside surface that is much more granular and a coarser material.

In another envelope I have some random pieces picked up of spalls that the Indians had removed that I have treated. Then I have taken a series of flakes showing the difference in character. It is very evident from these the difference in character in heated and unheated stone. From the Antelope Creek Indian quarry I get quite a variety of material. Some is brightly colored, purples, and reds and yellows and even some with moss inclusions. I find the texture of the material varies and each variety takes a different oven temperature to properly prepare it for working. I have a piece of stone from this quarry that is white with inclusions of purple and pink. When heating this particular stone, I got perfectly heated results on either end, but the center portion was overheated, or overdone, and it had a tendancy to check. Yet from the surface of the material, it is difficult to see any change of texture or to determine why the center portion of this particular flake would not stand this degree of heat without checking. However, with some of the clear material - a little finer grain - I found it does not require as much heat to alter this stone to the proper working stage. When I put a tray containing several chips from this same quarry in the oven, I found that some of the chips would check from overheating and yet they were heated at the same degree and cooled in the same manner and they were covered with approximately the same amount of sand. I do not have a temperature control on my oven, but I time the heating and as soon as the temperature reached approximately 1100 degrees which I have timed for 30 minutes, I turn off the oven and let it cool for at least 16 to 18 hours before I remove the tray of stones. I had one group of flakes which I heated only to 1000 degrees and then removed a piece of stone from the oven and, holding it with a pair of pliers, I removed a chip from the heated stone and I could see that the stone had not altered. I have included this piece of stone - heated to 1000 degrees - and there is almost no change, so I do find that there is a critical point in heating when the crystallization changes. The thinner the chips used for heating, the better the results. In using more massive stone I found it more difficult to obtain the proper heat all the way thru the stone. If the heat was built up slowly over a long period of time then perhaps it would not require as high a degree of heat, but this will have to be proved later after I have some sort of oven control.

I have included also in these specimens a piece of opal which might be confused if you would pick up surface material in a camp site. The opal has a natural lustre to it and heating just checks it, for opal will stand very little heat. However, it does resemble a heat-treated stone and it would be difficult to tell with just the naked eye if it was a heat treated stone or opal. All of the pieces of stone that I have used in this experiment are Indian material I mean by that, that they were obtained from an Indian quarry site or from campsites. On these tests I used only material from the Antelope Creek Quarry, for there I found not only a large quantity of stone but also much variety and felt this was ideal for testing.

If a study is made of the materials found from different campsites, cave sites and surface finds, and one will watch for the original side or the side of the stone when it was freshly broken by the Indian in order to thin it down prior to the heat-treating, he will see evidence that this particular phase was of extreme importance in the flintworking industry. I also believe that we will find that is was almost impossible to work fine artifacts with the fine pressure flaking without the heat treatment. We might even compare this method of treating stone to tempering steel. It was quite a step forward for the Indian when he discovered the help of heat treating stone. How to date the discovery of heat-treating stone, I do not know. But I do know that many of the Folsom points that I see, from my experience show that they have been heat-treated. Being a stone collector and having seen materials from all over the Western United States and also other parts of the country, I have yet to see material

from a quarry site out of the earth that has the lustre and the sheen and the ease of working of a heated piece.

It is hard for me to explain to someone who does not do flintworking but I, for one, in doing this flaking find that there is a great deal of difference and ease of working the stone after it has been treated. When I am working an untreated piece of natural flint, I have trouble removing a flake one half inch long, but with heat-treated material I have removed flakes two and one fourch inches long manually, which is some proof of the character change in the thermal treatment of stone.